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ON THE WAVE-LENGTH OF THE SECOND LINE IN
THE SPECTRA OF THE NEBULÆ.

BY JAMES E. KEELER.

In testing the results published in a paper* on the motions of the planetary nebulæ in the line of sight, I made a few measurements which give, incidentally, the wave-length of the second nebular line. Although the method employed (that of angular measurement with a graduated circle) was not the most favorable for entire accuracy, the high dispersion which was used gives the results a degree of precision which is, at least, equal to that attained by previous observers, and it therefore seems worth while to give a short account of the observations.

The object of the observations was to ascertain whether (as was altogether probable) the second nebular line was equally displaced with the first in the spectra of those nebulæ for which such differences of position were detected, or whether the differences of position were confined to the brightest line alone, a possible, though highly improbable, alternative. For this purpose two bright nebulæ were chosen, in the spectra of which the difference of position of the brightest line was nearly the greatest observed, and the distance between the first and second lines was measured in each. The arrangement of the apparatus was the same as in the observations described in my former paper, and it is only necessary to say, in addition to the description there given, that the observing telescope is provided with a twelve-inch circle divided on the edge, on silver, to 10', and read by two opposite verniers to 10". A small electric lamp, in a lantern on the lower end of the observing telescope, throws light on the ground-glass shade of one of the reading microscopes, and also illuminates the wires of the micrometer. The color of the light which enters the micrometer-box can be varied to approximately match any part of the spectrum, by means of a revolving disc carrying colored glasses. Only one vernier is ordinarily read, the eccentricity being very small. Means are provided for making every adjustment that the observer could wish, and I have to thank Mr. BRASHEAR for various useful additions to the original design of the instrument.

* Page 265 of the present number.

In making the measures, the micrometer-head was first set to about 2'.60. The coarse wire was then in the center of the field, and the reading on the slit, when the telescope was brought into line with the collimator, was very nearly 0°. The circle was then set to 140°, making the angle between the axes of the telescopes about 40°, and the grating turned until the brightest nebular line in the fourth spectrum fell upon the coarse micrometer wire. The telescope was directed alternately upon the first and second nebular lines by turning the tangent screw, the circle being read for each setting, until as many measures were obtained as was desirable. The illumination, controlled by a switch in the hand of the observer, was used only in bringing the micrometer wire approximately on the nebular line, the final setting being made by occulting the line in a dark field. The reflected image of the slit from the surface of the grating was then observed, and finally the slit itself, the grating being removed (or turned edgewise). These observations give all the data for computing, by the formulæ for the diffraction grating, the wave-length of the brightest line and the difference of wave-length of the first and second lines, the absolute wave-length to be regarded as merely approximate and only useful as a check.

The formula for the reflecting grating is :

$$n\lambda = d(\sin \psi - \sin \phi)$$

in which ϕ = angle between the normal to the grating and the incident ray.

ψ = angle between the normal to the grating and the diffracted ray (ϕ and ψ being measured in opposite directions from the normal).

λ = wave-length.

n = order of spectrum.

d = distance between centres of lines of the grating.

For two rays measured in same position of the grating,

$$n(\lambda_1 - \lambda_2) = d(\sin \psi_1 - \sin \psi_2).$$

The nebulae selected were *G. C. 4373* in *Draco* and *N. G. C. 7027* in *Cygnus*, for which the positions of the brightest line, corrected for the earth's motion, are respectively λ 5004.85 and λ 5006.13. Observations of *G. C. 4373* on the night of September 19th, gave the following data :

Circle reading on brightest nebular line, . . . $\begin{smallmatrix} 0 \\ 140 \end{smallmatrix} \begin{smallmatrix} ' \\ 1 \end{smallmatrix} \begin{smallmatrix} '' \\ 40 \end{smallmatrix}$
 Distance between first and second lines, from
 ten measures, $= \Delta\psi$ $1 \ 8 \ 23 \pm 6''$
 Circle reading on reflection of slit, ... $214 \ 32 \ 30$
 Circle reading on slit, ... $0 \ 1 \ 10$
 $n = 4.$

Hence, $\psi_1 = 57^\circ 15' 10''$, $\psi_2 = 56^\circ 6' 47''$, $\phi = -17^\circ 15' 40''$.

For this grating, $d = \frac{1}{14438}$ in. $= 17592.1$ tenth-metres.

Substituting in the formulæ, $\lambda_1 = 5004.1$, which is sufficiently near
 o the true value, and $\lambda_1 - \lambda_2 = \Delta\lambda = 48.05$ tenth-metres.

The only instrumental constant liable to change during the course
 of the observations, on account of flexure, etc., is the direction of
 the normal to the grating; but the distance between the nebular
 lines is very little affected by a small change in the position of the
 grating, as may be seen by differentiating the expression for $\Delta\psi$ with
 respect to ϕ . A change of $2'$ in ϕ produces a change of only $6''$ in
 $\Delta\psi$.

The following table exhibits the results of four different series of
 measurements, which are all of about the same weight :

DATE.	NEBULA.	$\Delta\psi$	$\Delta\lambda$
		$\begin{smallmatrix} 0 \\ 1 \end{smallmatrix} \begin{smallmatrix} ' \\ 8 \end{smallmatrix} \begin{smallmatrix} '' \\ 25 \end{smallmatrix}$	<i>tenth-metres.</i>
Sept. 3	<i>N. G. C. 7027</i>	$1 \ 8 \ 25$	48.07
Sept. 19	<i>N. G. C. 7027</i>	$1 \ 8 \ 2$	47.82
Sept. 18	<i>G. C. 4373</i>	$1 \ 8 \ 10$	47.92
Sept. 19	<i>G. C. 4373</i>	$1 \ 8 \ 23$	48.05
Mean			47.96

From these observations, the mean of the measured distances
 between the nebular lines is, for *N. G. C. 7027*, $1^\circ 8' 14''$, and for
G. C. 4373, $1^\circ 8' 17''$; but the difference of position of the lower
 line for the two nebulae is, from the table on page 278, 1.28 tenth-
 metres, or about $1' 50''$ in angular measure, the motion of the earth
 having very little effect at the time of observation on either nebula,
 and this is so much greater than the error of measurement that it is
 safe to conclude that the second line in both nebulae is equally dis-
 placed with the first line, and that in both nebulae the lines have the

same origin. Considering the small differences in the above table to be due to errors of observation, we have 47.96 tenth-metres for the difference of position of the two lines; hence the wave-length of the second line is

for *N. G. C. 7027* 4958.2 tenth-metres
 for *G. C. 4373* 4956.9 “

or for the mean of the ten nebulae on page 278, 4957.7 tenth-metres.

The values obtained by other observers are as follows :

HUGGINS λ 4957.0
 D'ARREST 4956.6
 COPELAND 4958.0

THE MOTION OF *ARCTURUS* IN THE LINE OF SIGHT.

BY JAMES E. KEELER.

While the spectroscopic observations of nebulae described on page 265 *et seq.* were in progress, a few measures of the displacement of the *D* lines in the spectrum of *Arcturus* were made, and these measures, when corrected for the orbital motion of the earth, gave a motion of the star toward the solar system of only four English miles per second. In view of the fact that observations of the planets with the same apparatus gave results closely in accordance with theory (see, for example, the table on page 270), it appeared to be probable that the large motion of over fifty miles per second, hitherto accepted for this star, was erroneous, although the discrepancy led to a careful examination of all possible sources of error in our own apparatus. Without entering into the details of the various experiments which were made, it may be stated that no other evidence could be found for the existence of constant errors than the discordance between the measured motion of *Arcturus* and that which has been commonly accepted.

In No. 2896 of the *Astronomische Nachrichten*, Professor H. C. VOGEL gives the motions of a number of stars in the line of sight, determined by a photographic method with a much higher degree of precision than that of any previous measurements. *Arcturus* was not included in the list, but measures of the motion of this star have been kindly supplied by Professor VOGEL, with permission to publish